

# Evaluating Low-Cost Nephelometers

*Challenges and Opportunities in High Exposure Environments*



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# Meet The Team



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Prasannaa Kumar  
Project Scientist



Bavath  
Project Scientist



Saran Raj  
Project Assistant

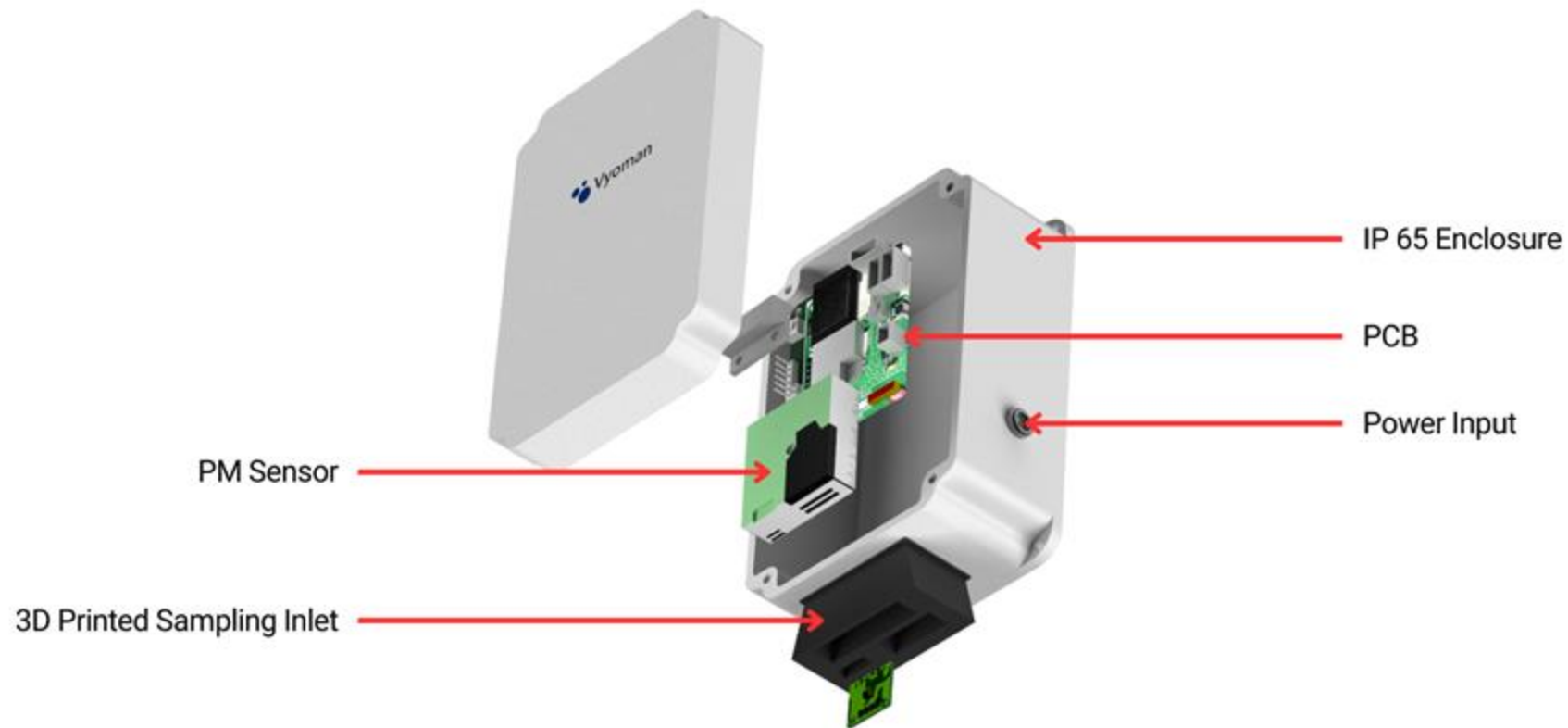


Jay Dhariwal  
Assistant Professor



Seshan Srirangarajan  
Associate Professor

# Design and Development of Monitors



# Our Work

## Collocated Studies



IIT Delhi - Sensor Network



Delhi - Site II  
DPCC Station, Aurobindo Marg.



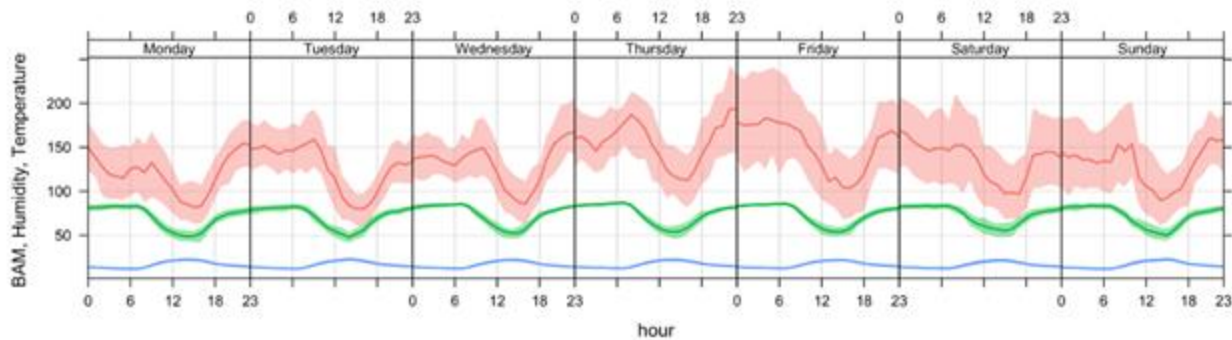
Jodhpur



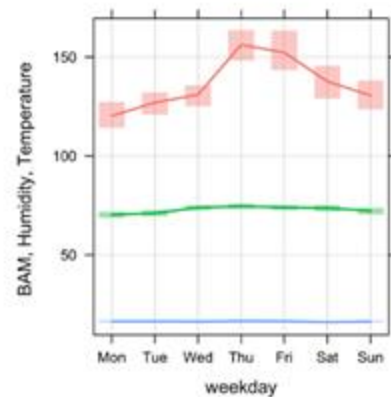
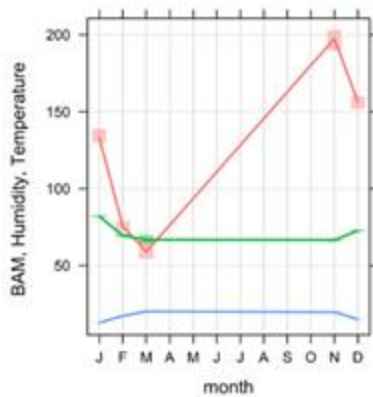
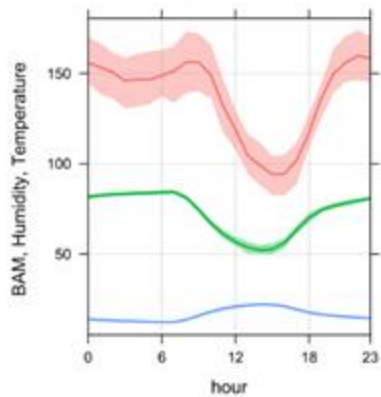
Delhi - Site I  
IMD Station, Aurobindo Marg.



# Site Conditions

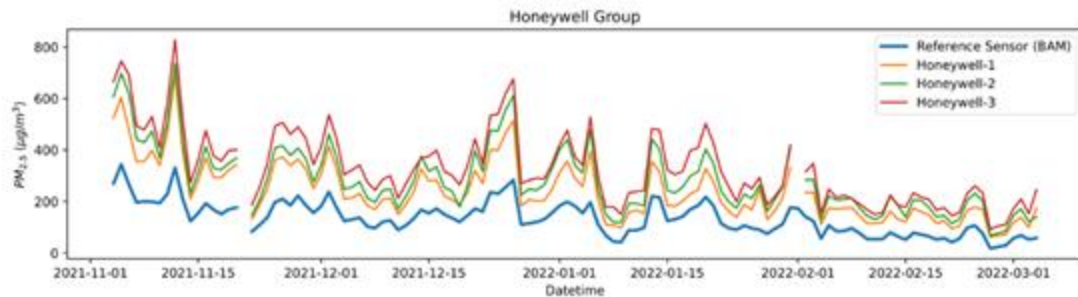
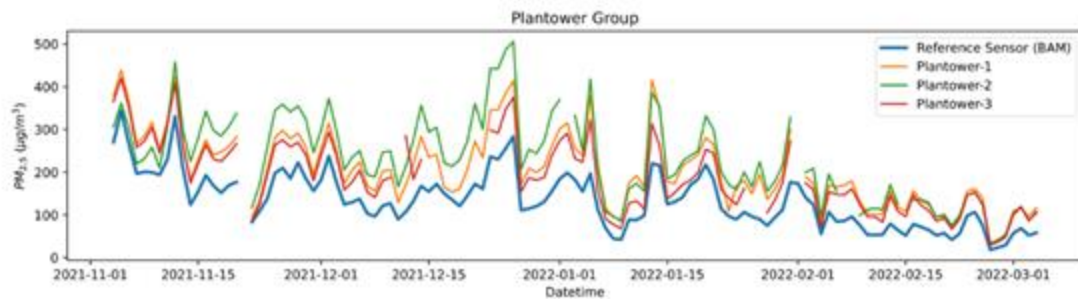
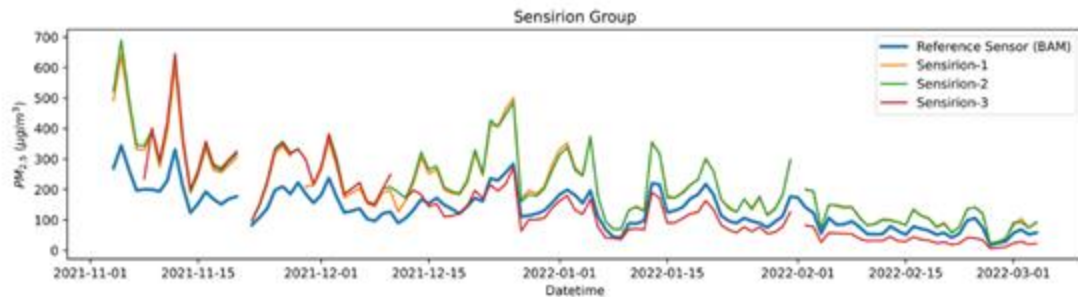


■ BAM ■ Humidity ■ Temperature

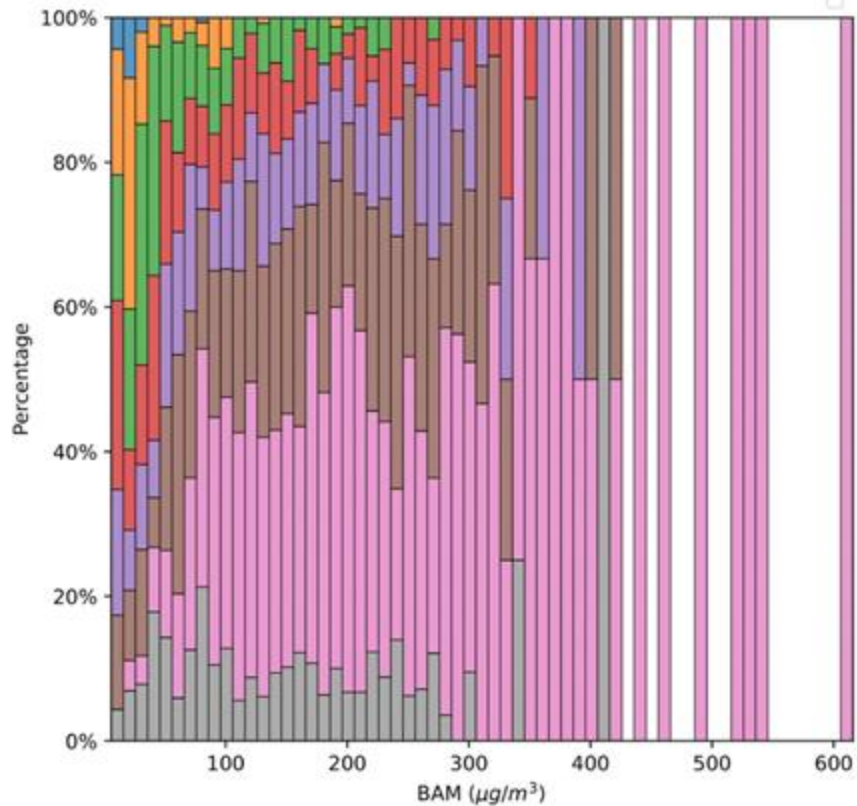
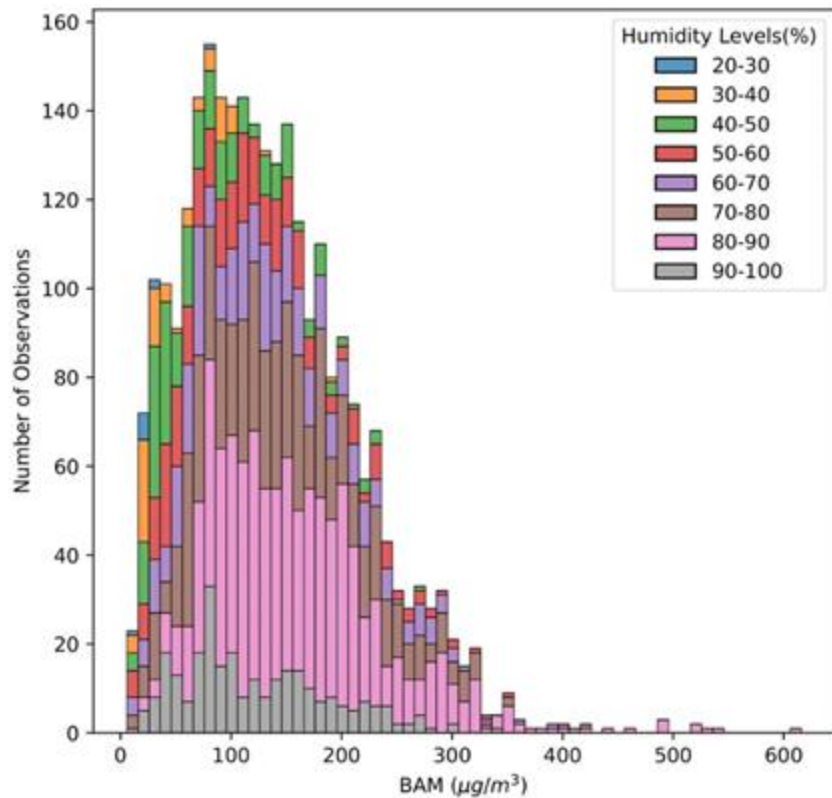


mean and 95% confidence interval in mean

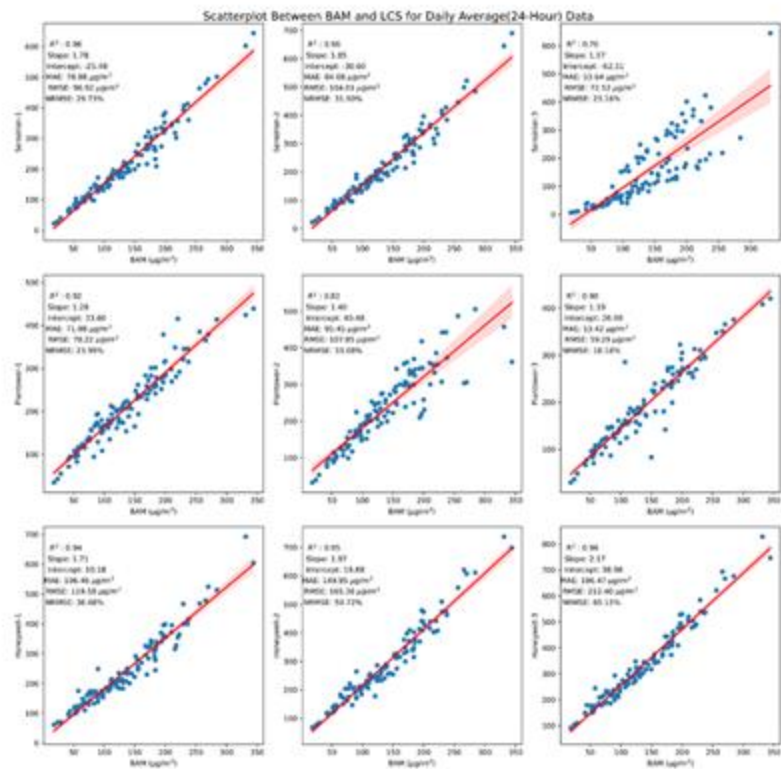
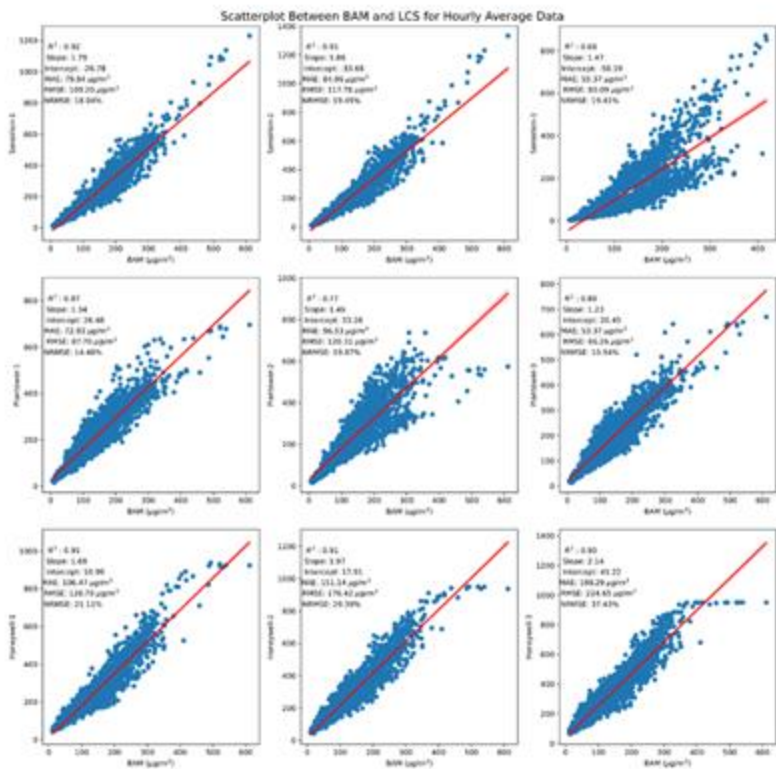
# Daily Average



# Humidity Levels



# Correlation





# Performance Metrics

Performance Metric		Target Value	
		Base Testing	Enhanced Testing*
Precision	Standard Deviation (SD)	$\leq 5 \mu\text{g}/\text{m}^3$	No target values recommended; report results
	-OR- Coefficient of Variation (CV)	$\leq 30\%$	
Bias	Slope	$1.0 \pm 0.35$	
	Intercept (b)	$-5 \leq b \leq 5 \mu\text{g}/\text{m}^3$	
Linearity	Coefficient of Determination ( $R^2$ )	$\geq 0.70$	
Error	Root Mean Square Error (RMSE) or Normalized Root Mean Square Error (NRMSE)	$\text{RMSE} \leq 7 \mu\text{g}/\text{m}^3$ or $\text{NRMSE} \leq 30\%^\dagger$	

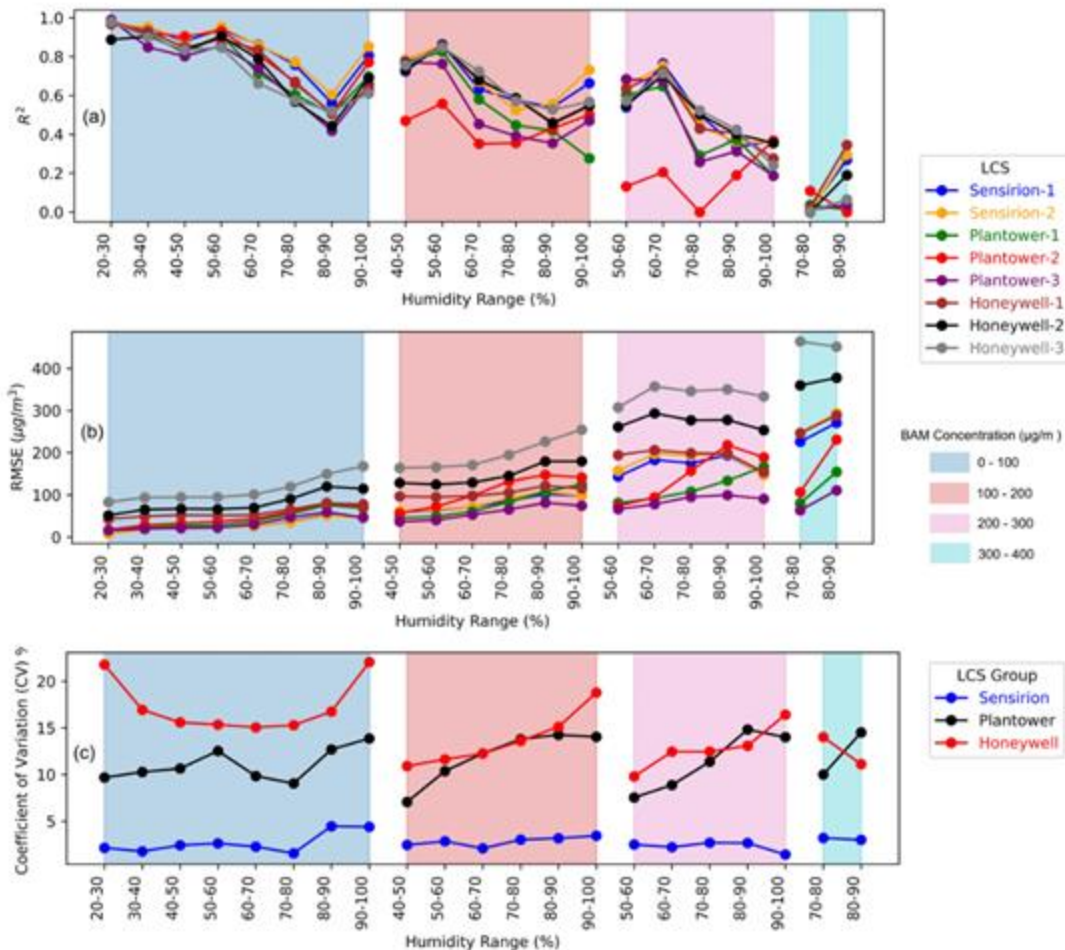
# Correlation (Binned)

		$R^2$							
BAM ( $\mu\text{g}/\text{m}^3$ )	Humidity (%)	Sensirion-1	Sensirion-2	Plantower-1	Plantower-2	Plantower-3	Honeywell-1	Honeywell-2	Honeywell-3
0-100	20-30	0.9679	0.9673	0.9716	0.9835	0.9901	0.9662	0.8877	0.9783
	30-40	0.9485	0.9518	0.919	0.9215	0.8503	0.9317	0.9027	0.8999
	40-50	0.8788	0.896	0.8245	0.9072	0.8077	0.8498	0.83	0.8295
	50-60	0.9427	0.9502	0.9083	0.9318	0.8824	0.8864	0.9055	0.8427
	60-70	0.8694	0.856	0.7188	0.802	0.7406	0.8521	0.8141	0.6671
	70-80	0.7552	0.7718	0.616	0.6914	0.5767	0.6592	0.6114	0.598
	80-90	0.5624	0.604	0.4984	0.5063	0.416	0.5083	0.4371	0.5185
	90-100	0.8033	0.8534	0.6996	0.7861	0.6637	0.6426	0.718	0.6084
100-200	40-50	0.724	0.7849	0.7736	0.4695	0.7709	0.756	0.7326	0.7561
	50-60	0.8638	0.8581	0.8253	0.5582	0.7631	0.856	0.8551	0.8481
	60-70	0.6331	0.6699	0.5806	0.3513	0.4532	0.6781	0.6807	0.7247
	70-80	0.5743	0.5258	0.447	0.3551	0.3913	0.5858	0.5864	0.5717
	80-90	0.5404	0.5588	0.419	0.4311	0.3545	0.46	0.4554	0.5272
	90-100	0.6633	0.7315	0.2767	0.5003	0.4699	0.5512	0.5461	0.567
200-300	50-60	0.5391	0.6475	0.6038	0.1321	0.6843	0.6333	0.5491	0.5727
	60-70	0.765	0.7536	0.6468	0.2053	0.6747	0.7251	0.7043	0.714
	70-80	0.501	0.4462	0.2911	0.0004	0.2579	0.4293	0.5022	0.5232
	80-90	0.3358	0.3588	0.3745	0.1901	0.3132	0.4042	0.4018	0.4241
	90-100	0.3645	0.3583	0.1876	0.3681	0.187	0.275	0.3552	0.24
300-400	70-80	0.0132	0.0069	0.104	0.0144	0.0355	0.0029	0.0007	
	80-90	0.2693	0.2945	0.0107	0.0012	0.0783	0.3451	0.2907	0.2273

# Error (Binned)

Mean Absolute Error (MAE)									
BAM ( $\mu\text{g}/\text{m}^3$ )	Humidity (%)	Sensirion-1 ( $\mu\text{g}/\text{m}^3$ )	Sensirion-2 ( $\mu\text{g}/\text{m}^3$ )	Plantower-1 ( $\mu\text{g}/\text{m}^3$ )	Plantower-2 ( $\mu\text{g}/\text{m}^3$ )	Plantower-3 ( $\mu\text{g}/\text{m}^3$ )	Honeywell-1 ( $\mu\text{g}/\text{m}^3$ )	Honeywell-2 ( $\mu\text{g}/\text{m}^3$ )	Honeywell-3 ( $\mu\text{g}/\text{m}^3$ )
0-100	20-30	5.37	5.36	16.01	15.54	12.89	41.67	49.70	81.85
	30-40	13.72	13.50	20.38	24.52	15.06	47.64	62.72	90.82
	40-50	17.87	17.10	22.98	28.03	16.31	50.02	64.10	91.85
	50-60	19.02	18.55	25.34	32.40	18.38	49.69	63.84	91.54
	60-70	21.62	21.22	33.06	38.80	25.92	50.97	67.09	96.94
	70-80	31.02	30.04	47.68	52.23	38.93	62.44	85.15	115.19
	80-90	47.52	45.94	69.22	74.10	50.40	75.50	113.27	144.42
90-100	41.45	41.28	61.49	66.93	38.89	73.81	108.69	160.91	
100-200	40-50	52.82	55.19	40.88	47.84	32.01	91.66	122.16	159.59
	50-60	59.52	60.90	44.26	67.48	35.47	90.42	119.52	160.78
	60-70	62.88	63.85	53.31	87.74	44.24	90.30	122.15	165.40
	70-80	75.56	81.72	74.35	120.27	56.21	98.24	137.07	187.56
	80-90	90.49	95.81	99.59	134.50	71.89	112.40	170.80	218.41
	90-100	91.95	93.42	113.65	135.04	66.16	108.73	174.97	249.03
200-300	50-60	137.63	151.16	78.07	58.28	62.96	189.24	255.47	301.94
	60-70	172.75	186.22	87.04	69.85	73.13	199.36	282.82	345.21
	70-80	163.72	177.90	100.12	132.84	86.12	187.54	266.26	332.53
	80-90	178.77	182.18	125.65	203.08	89.51	185.86	266.40	340.44
	90-100	134.83	135.88	149.57	180.77	80.15	140.64	243.19	325.36
300-400	70-80	219.93	236.70	77.06	82.92	59.03	237.51	351.68	452.56
	80-90	255.77	273.18	141.13	205.05	94.02	271.53	362.59	432.49

# Granular Analysis



# Suggestions



Hourly average performance metrics for LCS evaluation



New guidelines for high ambient exposure conditions



Should include binning strategy for LCS performance evaluation instead of going ahead for entire range

**Thank You.**